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(54) **ESTIMATING MOTION OF AN EVENT CAPTURED USING A DIGITAL VIDEO CAMERA**

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G06T 5/50	(2006.01)
G06T 7/20	(2006.01)
G08B 13/196	(2006.01)
H04N 7/18	(2006.01)

(52) **U.S. Cl.**

CPC ***G06K 9/00771*** (2013.01); ***G06T 5/50*** (2013.01); ***G06T 7/2033*** (2013.01); ***G08B 13/19608*** (2013.01); ***H04N 7/188*** (2013.01); *G06K 2009/00738* (2013.01); *G06T 2207/10016* (2013.01); *G06T 2207/30232* (2013.01)

(58) **Field of Classification Search**

CPC G06K 9/00771; G06K 2009/00738; G06T 5/50; G06T 7/2033; G06T 2207/30232; G06T 2207/10016; H04N 7/188; G08B 13/19608

USPC 382/103, 104, 254, 282; 348/155, 148, 348/143

See application file for complete search history.

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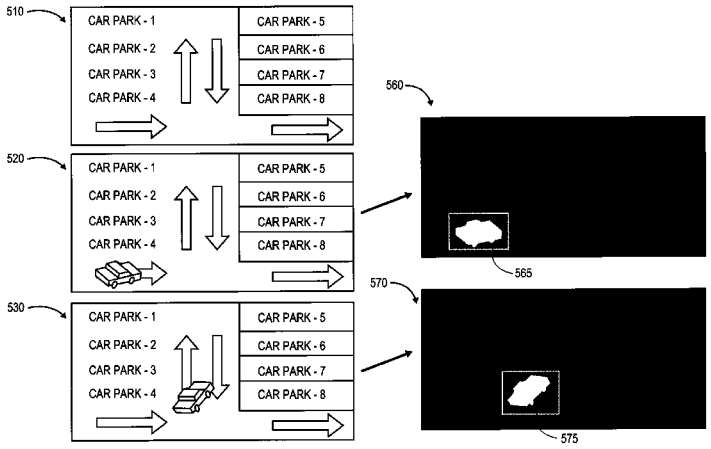
(57) **ABSTRACT**

An event aware video system (EAVS) is to capture video frames during a first time period and process events in the video frames before transferring the processed data to a central computing system. The EAVS may establish a present no-event frame from the video frames by marking the last frame as the present no-event frame if the difference between adjacent pair of video frames is less than a threshold value. The EAVS may establish an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame is greater than the threshold value. The EAVS may provide event information including motion vectors to a central computing system by performing one-dimensional search on a moving object of the event frame, wherein the motion vectors may represent displacement of objects moving within the moving object.

22 Claims, 7 Drawing Sheets



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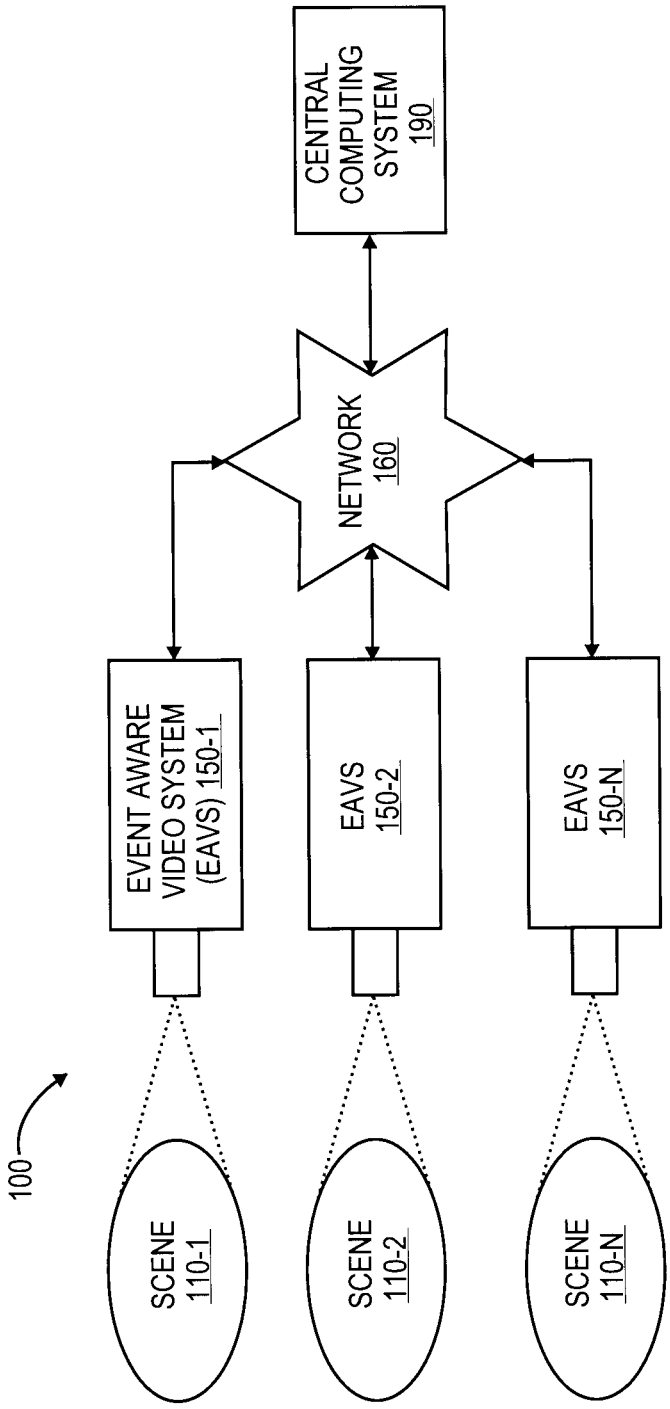

CENTRAL COMPUTING SYSTEM 190
NETWORK 160
EVENT AWARE VIDEO SYSTEM (EAVS) 150-1
EAVS 150-2
EAVS 150-N
SCENE 110-1
SCENE 110-2
SCENE 110-N
100

FIG. 1

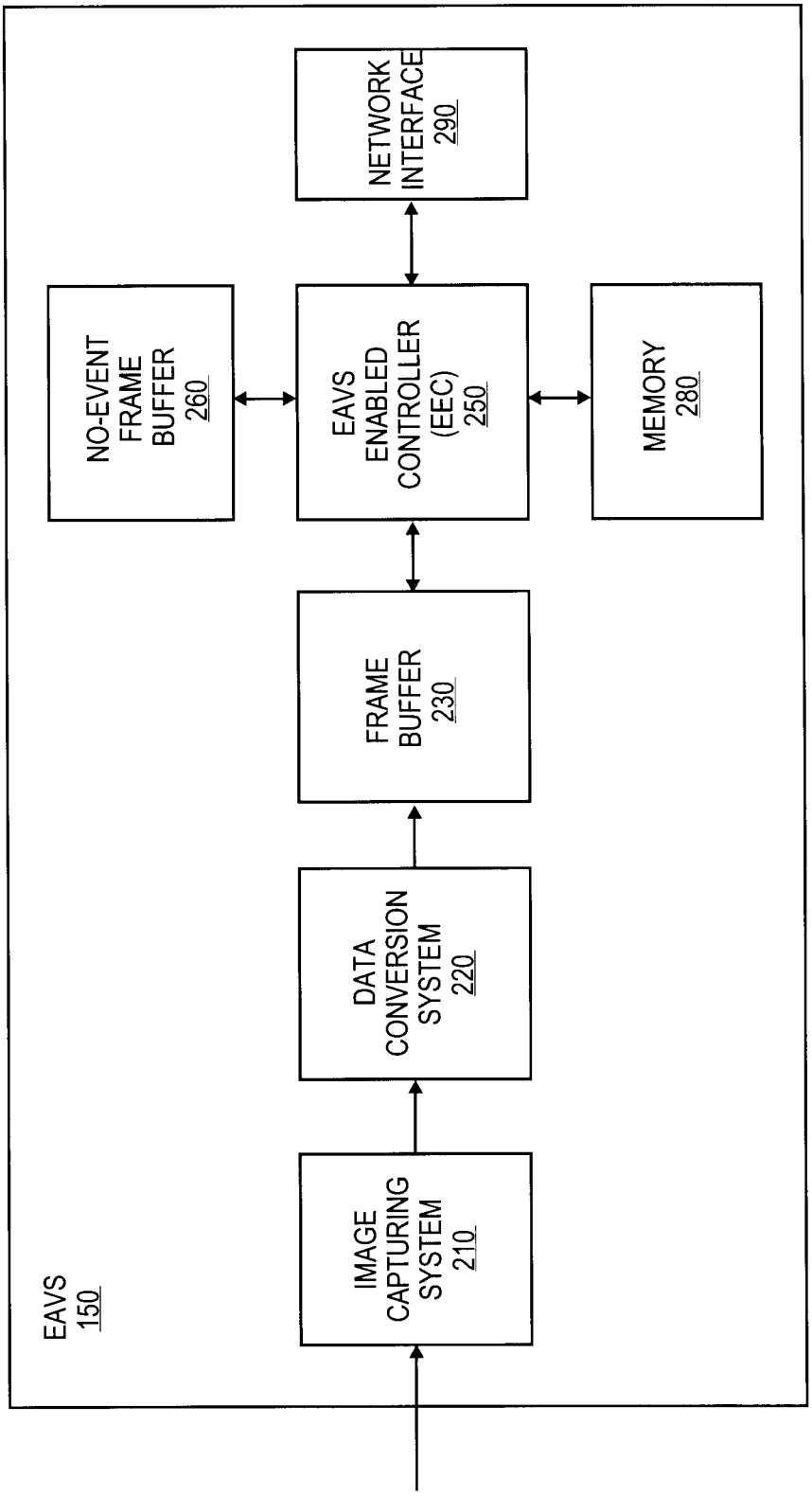
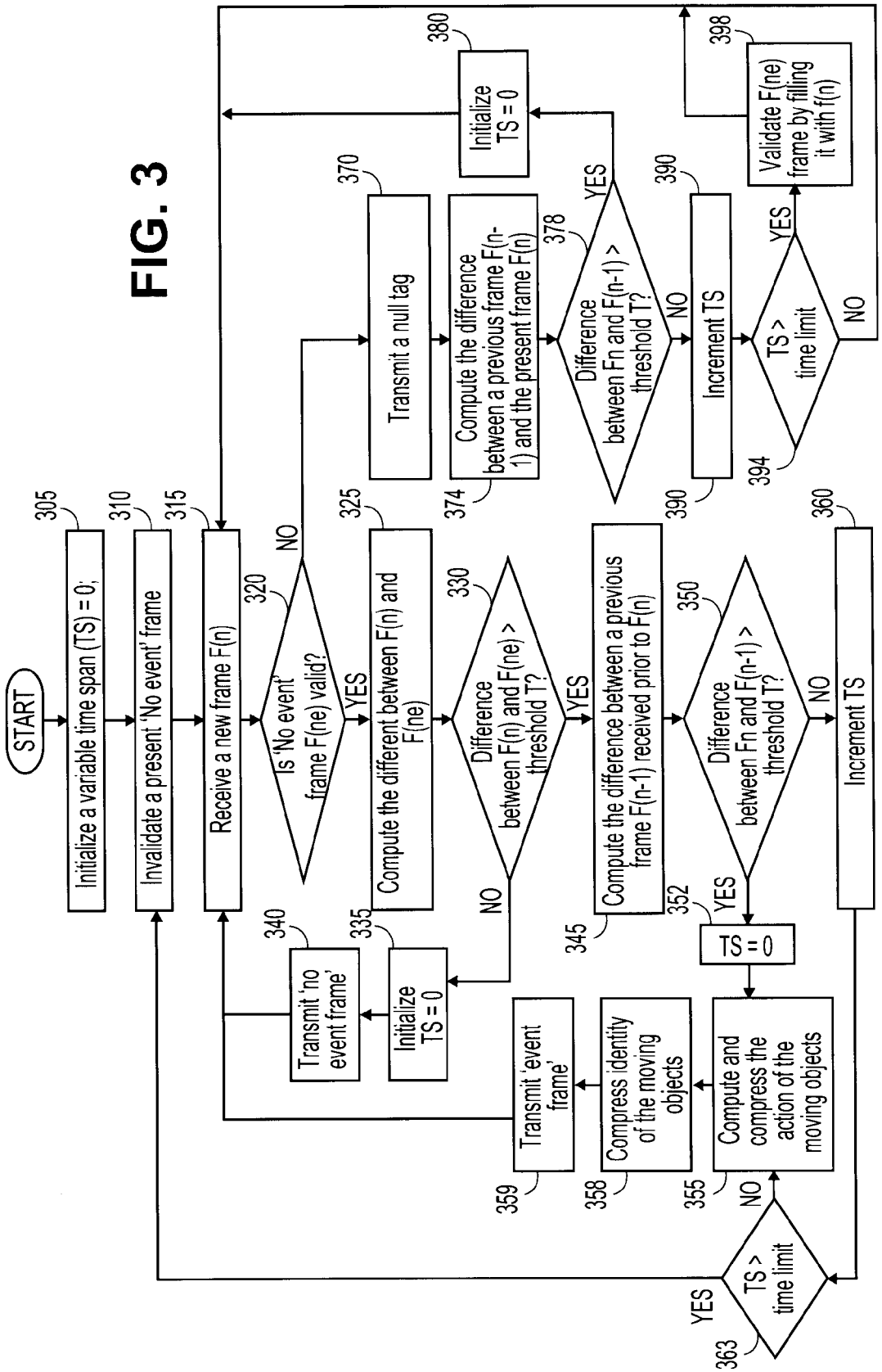

EAVS
150
IMAGE CAPTURING SYSTEM
210
DATA CONVERSION SYSTEM
220
FRAME BUFFER
230
EAVS ENABLED CONTROLLER (EEC)
250
NO-EVENT FRAME BUFFER
260
MEMORY
280
NETWORK INTERFACE
290

FIG. 2

FIG. 3


START
Initialize a variable time span (TS) = 0;
305
Invalidate a present 'No event' frame
310
Receive a new frame F(n)
315
Is 'No event' frame F(ne) valid?
320
NO
YES
Compute the different between F(n) and F(ne)
325
Difference between F(n) and F(ne) > threshold T?
330
NO
YES
Initialize TS = 0
335
Transmit 'no event frame'
340
Compute the difference between a previous frame F(n-1) received prior to F(n)
345
Difference between Fn and F(n-1) > threshold T?
350
NO
YES
TS = 0
352
Increment TS
360
Compute and compress the action of the moving objects
355
Compress identity of the moving objects
358
Transmit 'event frame'
359
TS > time limit
363
NO
YES
Transmit a null tag
370
Compute the difference between a previous frame F(n-1) and the present frame F(n)
374
Difference between Fn and F(n-1) > threshold T?
378
NO
YES
Increment TS
390
TS > time limit
394
NO
YES
Initialize TS = 0
380
Validate F(ne) frame by filling it with f(n)
398

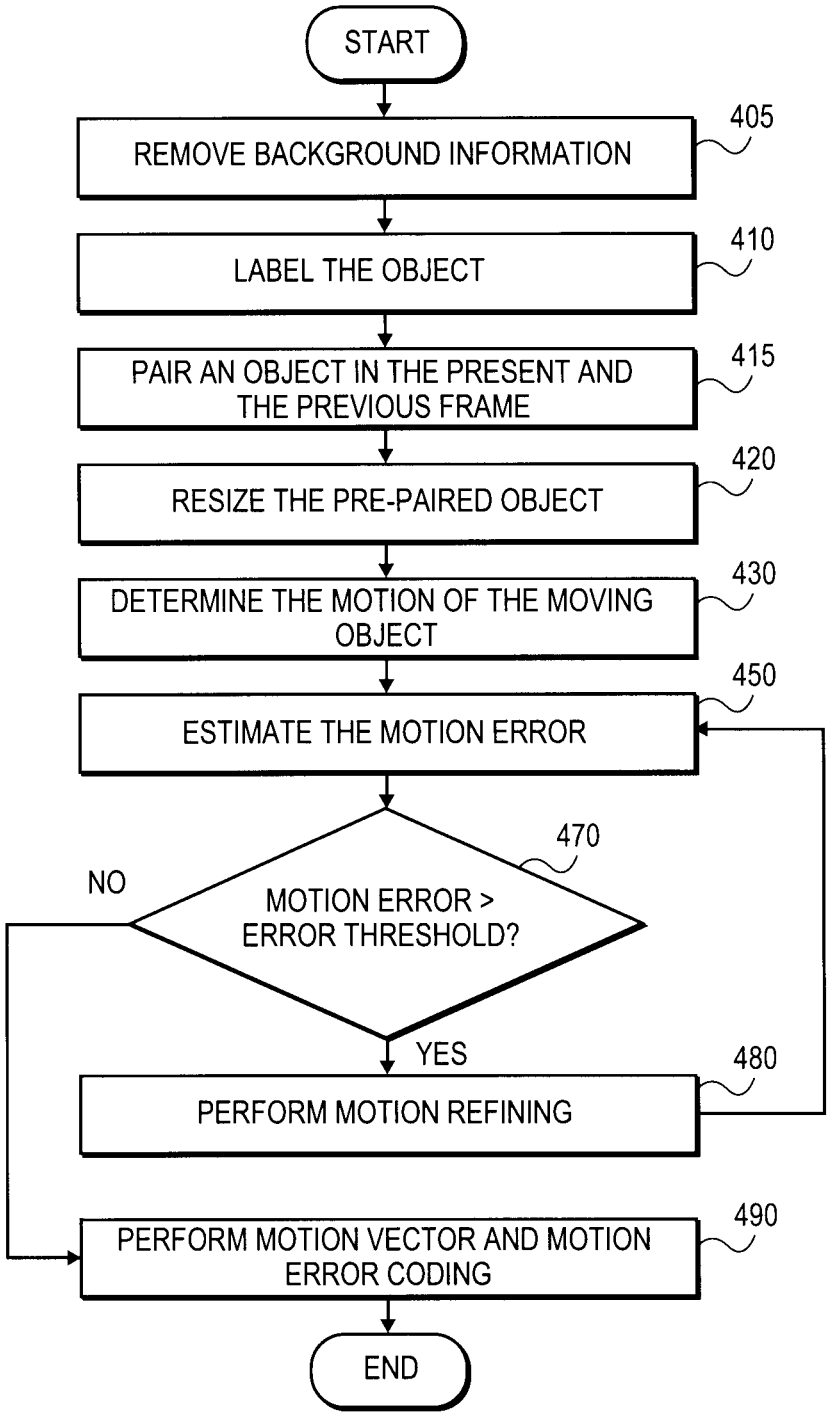
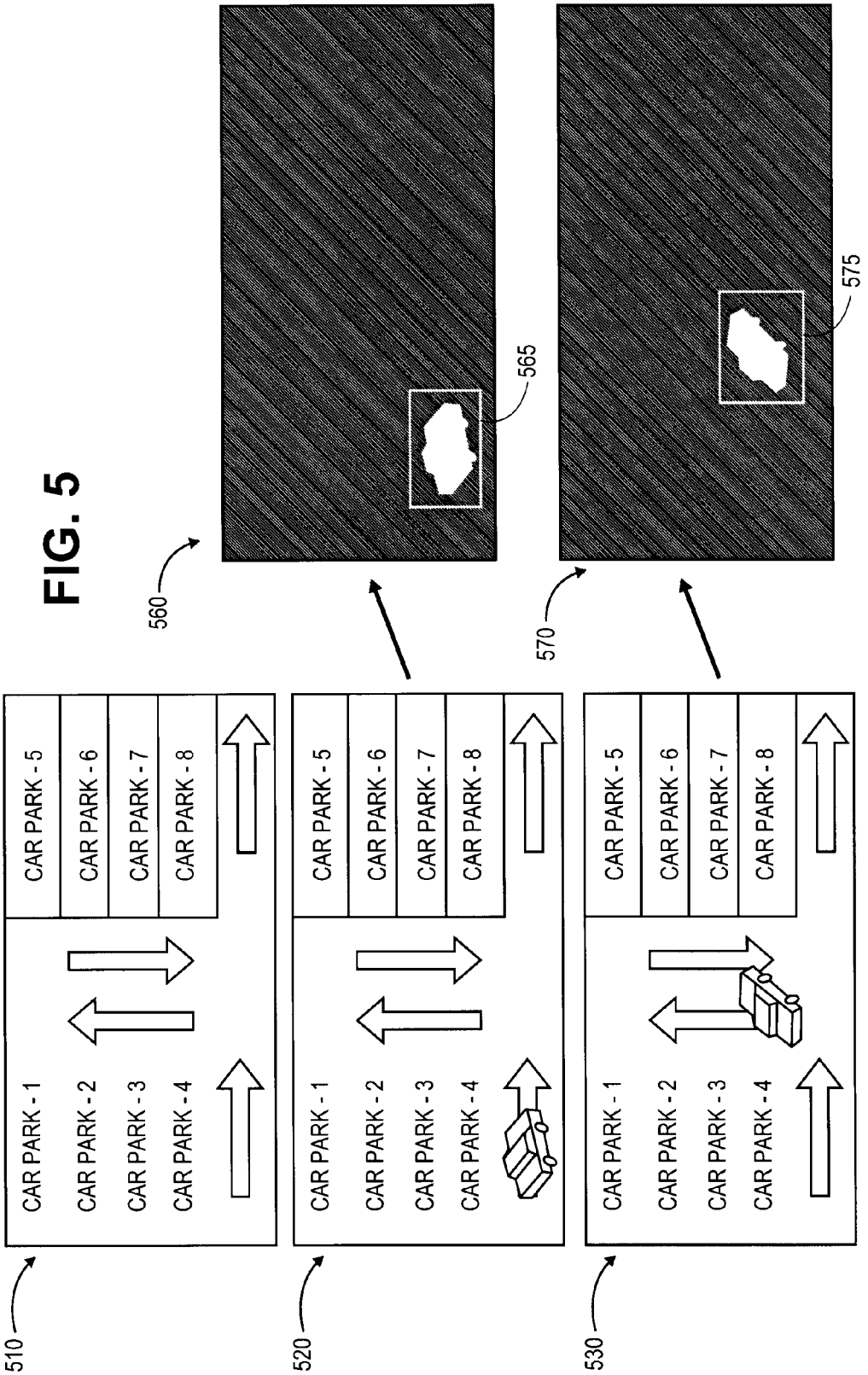

START
REMOVE BACKGROUND INFORMATION
405
LABEL THE OBJECT
410
PAIR AN OBJECT IN THE PRESENT AND THE PREVIOUS FRAME
415
RESIZE THE PRE-PAIRED OBJECT
420
DETERMINE THE MOTION OF THE MOVING OBJECT
430
ESTIMATE THE MOTION ERROR
450
470
MOTION ERROR > ERROR THRESHOLD?
NO
YES
PERFORM MOTION REFINING
480
PERFORM MOTION VECTOR AND MOTION ERROR CODING
490
END

FIG. 4

FIG. 5


CAR PARK - 1
CAR PARK - 2
CAR PARK - 3
CAR PARK - 4
CAR PARK - 5
CAR PARK - 6
CAR PARK - 7
CAR PARK - 8
510
520
530
560
565
570
575

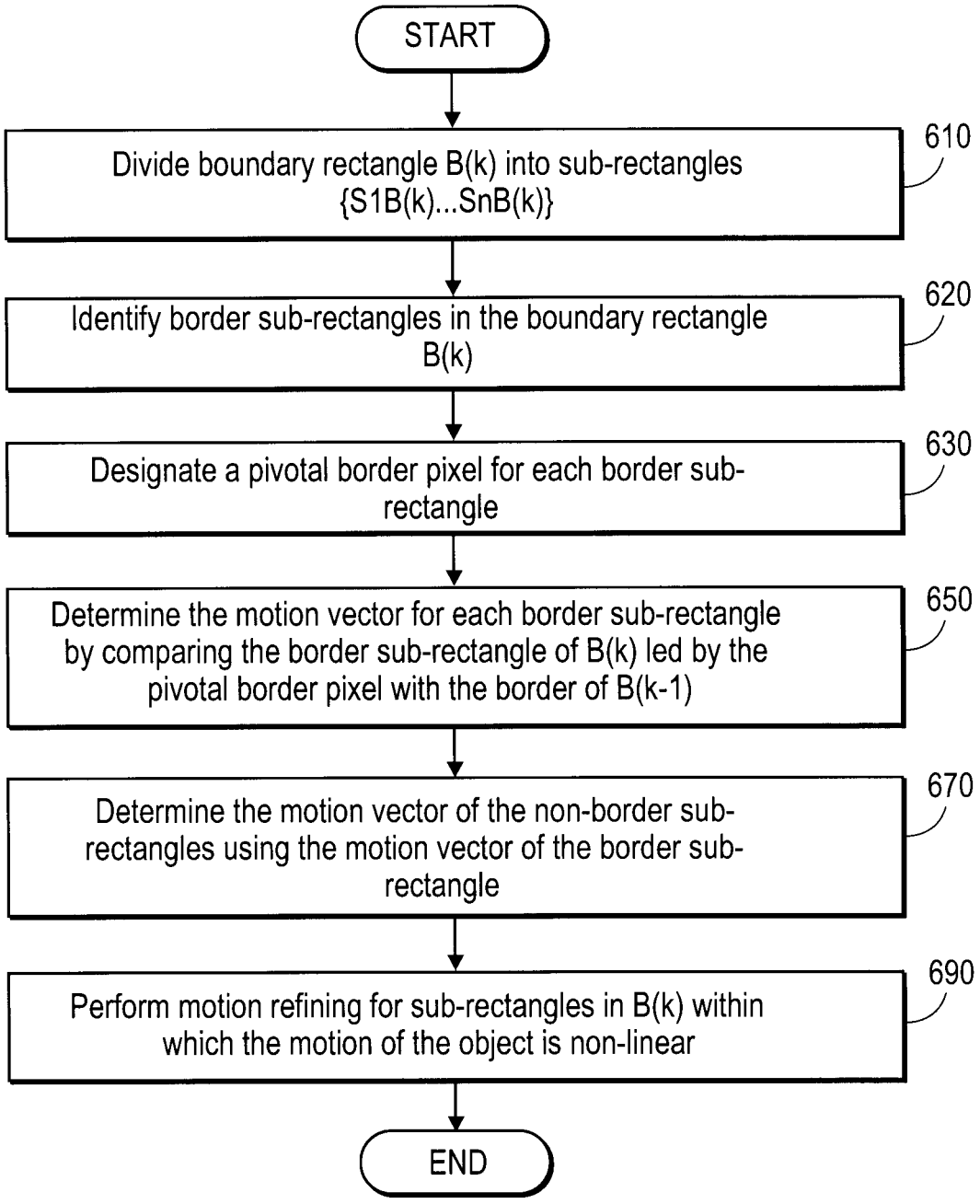

START
Divide boundary rectangle B(k) into sub-rectangles {S1B(k)...SnB(k)}
610
Identify border sub-rectangles in the boundary rectangle B(k)
620
Designate a pivotal border pixel for each border sub-rectangle
630
Determine the motion vector for each border sub-rectangle by comparing the border sub-rectangle of B(k) led by the pivotal border pixel with the border of B(k-1)
650
Determine the motion vector of the non-border sub-rectangles using the motion vector of the border sub-rectangle
670
Perform motion refining for sub-rectangles in B(k) within which the motion of the object is non-linear
690
END

FIG. 6

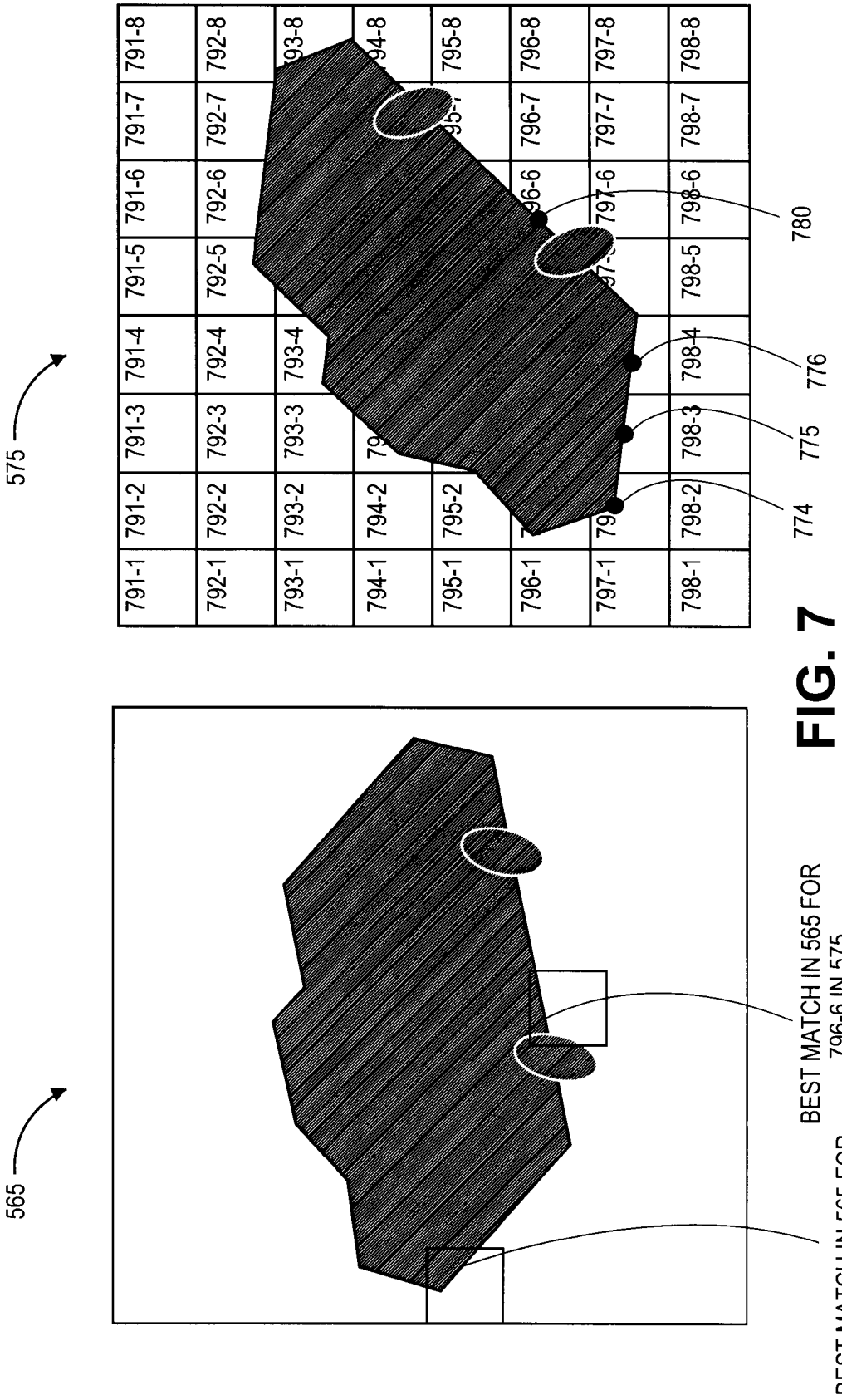

575
791-8
792-8
793-8
794-8
795-8
796-8
797-8
798-8
791-7
792-7
795-7
796-7
797-7
798-7
791-6
792-6
796-6
797-6
798-6
791-5
792-5
798-5
791-4
792-4
793-4
798-4
791-3
792-3
793-3
798-3
791-2
792-2
793-2
794-2
795-2
798-2
791-1
792-1
793-1
794-1
795-1
796-1
797-1
798-1
780
776
775
774
565
BEST MATCH IN 565 FOR 796-6 IN 575
BEST MATCH IN 565 FOR 797-2 IN 575

FIG. 7

ESTIMATING MOTION OF AN EVENT CAPTURED USING A DIGITAL VIDEO CAMERA

BACKGROUND

Video surveillance systems generally comprise a plurality of video cameras and each video camera may capture the image of a specific area within the view of the video camera. The video cameras may capture the data and compress the video data before sending the compressed data to a central computing system. The video data may be processed to estimate the motion of moving objects. However, using two-dimensional approach to estimate the motion may be computationally intensive.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention described herein is illustrated by way of example and not by way of limitation in the accompanying figures. For simplicity and clarity of illustration, elements illustrated in the figures are not necessarily drawn to scale. For example, the dimensions of some elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference labels have been repeated among the figures to indicate corresponding or analogous elements.

FIG. **1** illustrates a video surveillance system, including one or more event aware video system (EAVS) according to one embodiment.

FIG. **2** illustrates the event aware video system (EAVS) in which event capturing technique is supported according to one embodiment.

FIG. **3** is a flow diagram illustrating operations that may be performed by the EAVS according to one embodiment.

FIG. **4** is a flow diagram illustrating compute and compress operation performed by the EAVS according to one embodiment.

FIG. **5** illustrates one or more scenarios captured by the EAVS according to one embodiment.

FIG. **6** is a flow diagram illustrating one-dimensional search performed by the EAVS to determine the movement of the objects within the moving object according to one embodiment.

FIG. **7** is a bounding rectangle of the previous and present frame illustrating the determination of movement of objects within the moving object according to one embodiment.

DETAILED DESCRIPTION

The following description describes embodiments of a technique for capturing event information using a digital camera. In the following description, numerous specific details such as logic implementations, resource partitioning, or sharing, or duplication implementations, types and interrelationships of system components, and logic partitioning or integration choices are set forth in order to provide a more thorough understanding of the present invention. It will be appreciated, however, by one skilled in the art that the invention may be practiced without such specific details. In other instances, control structures, gate level circuits, and full software instruction sequences have not been shown in detail in order not to obscure the invention. Those of ordinary skill in the art, with the included descriptions, will be able to implement appropriate functionality without undue experimentation.

References in the specification to "one embodiment", "an embodiment", "an example embodiment", indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described.

Embodiments of the invention may be implemented in hardware, firmware, software, or any combination thereof. Embodiments of the invention may also be implemented as instructions stored on a machine-readable medium, which may be read and executed by one or more processors. A machine-readable medium may include any mechanism for storing or transmitting information in a form readable by a machine (e.g., a computing device).

For example, a machine-readable medium may include read only memory (ROM); random access memory (RAM); magnetic disk storage media; optical storage media; flash memory devices; electrical, optical, acoustical or other forms of propagated signals. Further, firmware, software, routines, and instructions may be described herein as performing certain actions. However, it should be appreciated that such descriptions are merely for convenience and that such actions in fact result from computing devices, processors, controllers, and other devices executing the firmware, software, routines, and instructions.

A video surveillance system **100**, which may support capturing event information in accordance with one embodiment, is illustrated in FIG. **1**. In one embodiment, the video surveillance system **100** may comprise event aware video system (EAVS) **150-1** to **150**-N, a network **160**, and a central computing system **190**. In one embodiment, the EAVS **150-1** to **150**-N may capture images in the scene **110-1** to **110**-N respectively.

The central computing system **190** may receive event information sent by the EAVS **150** and may perform further analysis. In one embodiment, the event information may comprise processed data generated by processing the event of a event frame. In one embodiment, the central computing system may conserve resources such as the processing cycles to further process the processed data. In one embodiment, the central computing system **190** may be used by a security officer, who may receive event information from EAVS **150-1** to **150**-N and monitor a large area comprising scenes **110-1** to **110**-N. In one embodiment, the central computing system **190** may represent a server system with large storage capability to store the event information for viewing at a later point in time as well.

The network **160** may comprise routers, switches, gateways, and similar other such devices to transfer event information between the EAVS **150** and the central computing system **190**. In one embodiment, the bandwidth of the network **160** may be conserved as the processed data representing the event information is transferred over the network **160**. The network **160** may represent a local area network, wide area network, metropolitan area network, internet, or any other such networks. In one embodiment, the network **160** may be wire based, or wireless based or a combination of both the wired and wireless technologies. The network **160** may support protocols such as transport control protocol/internet protocol (TCP/IP), user datagram protocol/internet protocol (UDP/IP), and such other similar protocols.

In one embodiment, the EAVS **150** may establish a 'no-event frame', compare an incoming frame with the no-event frame, and determine whether the incoming frame is an event frame or a no-event frame. In one embodiment, the EAVS **150** may determine that the incoming frame is an 'event frame' if the difference between the 'no-event frame' and the incoming frame is greater than a threshold value. In one embodiment, the 'no-event frame' may be used as a reference frame with which comparison is performed to detect the occurrence of an event.

In one embodiment, to establish the no-event frame, the EAVS **150** may capture video frames (P**1**, P**2**, . . . Pt) at regular intervals over a time period 'K" before marking a video frame as a 'no-event frame'. In one embodiment, the EAVS **150** may compare each adjacent pair of frames over the time period 'K' to determine whether a video frame is a 'no-event frame'. For example, the EAVS **150** may compare first pair of adjacent frames (P**2** and P**1**) and if the difference between the first pair of adjacent frames is less than the threshold value, the EAVS **150** may further compare second pair of adjacent frames (P**3** and P**2**). Like-wise, the EAVS **150** may compare adjacent frames {(P**4** and P**3**) . . . (Pt and Pt−1)} until the time period K is elapsed. If the difference between the adjacent pair of video frames is less than the threshold value, then the EAVS **150** may mark the most recent frame (Pt) as the no-event frame.

For example, if scene **110-1** represents an empty parking lot of shopping mall, the EAVS **150** may capture ten images P**1** to P**10** at time points T**1** to T**10** and compare the adjacent frames {(P**2**, P**1**), (P**3**, P**2**) . . . (P**10**, P**9**)} and if there is no activity detected, the image P**10** may be marked as the 'no-event frame'. Further, the EAVS **150** may capture an image P**11** at time point T**11**, compare the image P**11** with the image P**10** and if the difference between P**10** and P**11** is less than the threshold value, the image P**11** may be discarded, while maintaining P**10** as the no-event frame. In one embodiment, the EAVS **150** may mark the empty parking lot as a first no-event frame and store the first no-event frame in the no-event frame buffer **260**.

However, if an event such as a car entering the parking lot is detected in the image P**11**, the EAVS **150** may capture the event, mark the image as an 'event frame', and transmit the event to the central computer system **190**. In one embodiment, the EAVS **150** may compare P**11** and P**10** and the difference may be greater than the threshold value as an event (car entering the parking lot) has occurred. In one embodiment, the EAVS **150** may capture next ten images P**12** to P**21** and compare the adjacent pair of frames for detecting an event. If no event is detected, the frame P**21** comprising a car parked in the parking lot may be marked as the 'no-event frame'. It may be noted that, the first 'no-event frame' was an empty parking lot and the second no event frame is a parking lot with a car parked in the parking lot. In one embodiment, the EAVS **150** may replace the first 'no-event frame' with the 'second no-event frame' in the no-event frame buffer **260**. In one embodiment, the EAVS **150** may send the no-event frame at a first frame rate and at a first spatial quality to the central computing system **190**.

In one embodiment, the event aware video system EAVS **150** may capture a present video frame ($P+1^{th}$ video frame) and mark the present video frame as an 'event frame' if the difference between the ($P+1^{th}$ video frame) and (P^{th} video frame) is higher than the threshold value and if the ($P+1^{th}$ video frame) differs from the 'no-event' frame substantially. In one embodiment, the threshold value may be determined based on statistical or empirical methods. In one embodiment, the color value histogram (i.e. empirical probability distribution) at each pixel location is continuously collected from the no-event frame. If the color value at the same pixel location for the present video frame (P+1 video frame) falls outside a likelihood value of 90% of the no-event frame color distribution, that pixel may be marked as a candidate pixel for an event frame. In one embodiment, the likelihood value may be tunable system configuration parameter. Also, if there exists at least one large area of candidate pixels for the event frame in the present video frame ($P+1^{th}$ video frame), the entire frame may be marked as an event frame.

Also, in one embodiment, the entire frame may be divided into many small areas A**1**, A**2** . . . Ak. The threshold value may be imposed on the change in average color level of X number of pixels in each area A**1** of the present video frame compared to the same X pixels in the area A**1** of the previous video frame. In one embodiment, if the average color level of X pixels in the area A**1** changes by, for example, ten levels on the color scale (e.g., 0-255 color levels) then the EAVS **150** may mark the area A**1** as a candidate of the event frame. In one embodiment, if candidate small areas A**1**, A**2** . . . AJ connect together to form a larger area, then the present video frame (P+1 video frame) may be marked as the event frame. In one embodiment, the present video frame may be referred to as the 'event frame' and the previous video (Pth video frame) frame may be referred to as the 'no-event frame'.

In one embodiment, the event aware video system (EAVS) **150** may capture the event frame, extract event information from the event frame, analyze the event information, and transfer the event information to the central computing system **190**. In one embodiment, the first event information sent to the central computing system **190** may comprise the difference between the no-event frame (P^{th} frame) and a first event frame ($P+1^{th}$ frame). Also, the next event information may comprise the difference between the first event frame ($P+1^{th}$ frame) and the next event frame (P_next frame). In one embodiment, the EAVS **150** may send the event information at a second frame rate (SFR) and at a second spatial quality level (SQ). In one embodiment, the second frame rate may be higher than the first frame rate and the second spatial quality may be lower than the first spatial quality.

An event aware video system (EAVS) **150**, which may support capturing event information in accordance with one embodiment, is illustrated in FIG. **2**. The EAVS **150** may comprise an image capturing system **210**, a data conversion system **220**, a frame buffer **230**, EAVS enabled controller EEC **250**, a no-event frame buffer **260**, a memory **280**, and a network interface **290**.

The image capturing system **210** may capture the image and may comprise image capturing devices such as charge coupled devices (CCDs), CMOS sensors such as active pixel sensors, and similar such other devices. The image capturing system **210** may capture the optical signal and convert the optical signal into an electric signal. The data conversion system **220** may comprise analog-to-digital converters and other signal conditioning devices such as amplifiers, attenuators, noise cancellation devices and such other similar devices. The data conversion system **220** may receive the electrical signal from the image capturing system **210**, condition the electric signal, and provide the conditioned signal to the frame buffer **230**.

In one embodiment, the frame buffer **230** may store data representing the conditioned electric signal. In one embodiment, the frame buffer **230** may store a small number of frames (e.g., 2 to 3 frames) received from the data conversion system **230** that may be quickly retrieved by the EEC **250**.

The no-event frame buffer **260** may be used to store the 'no-event frame'. At any give time point, there may exist one

no-event frame, which may be stored in the no-event frame buffer **260**. In one embodiment, the no-event frame buffer **260** may comprise a small amount of high speed memory. However, the no-event frame buffer **260** may be updated at regular intervals of time and thus may be provided with a capability of supporting higher refresh rates.

The memory **280** may store instructions that may be used by the EAVS enabled controller EEC **250** to capture event information. The memory **280** may store data and/or software instructions and may comprise one or more different types of memory devices such as, for example, DRAM (Dynamic Random Access Memory) devices, SDRAM (Synchronous DRAM) devices, DDR (Double Data Rate) SDRAM devices, or other volatile and/or non-volatile memory devices used in a system such as the video surveillance system **100**.

The network interface **290** may receive data packets from the EAVS enabled controller **250** and may transfer the data packets over the network interface **290**. In one embodiment, the network interface **290** may comprise a network interface card (NIC) to transfer the data packets to an appropriate routing device of the network **150**.

The EAVS enabled controller (EEC) **250** may capture event information and transfer the event information to the central computing system **190**. In one embodiment, the EEC **250** may retrieve a video frame from the frame buffer **230** and determine whether the video frame is a 'no-event frame' or an 'event frame'. In one embodiment, the EEC **250** may extract the event information from the video frame if the video frame is an event frame. In one embodiment, the EEC **250** may mark the video frame as 'no-event frame' and may store the 'no-event frame' in the no-event frame buffer **260** if the video frame is a 'no-event frame'.

An operation of the EAVS enabled controller (EEC) **250** of the event aware video system (EAVS) **150** capturing the event information in accordance with one embodiment is illustrated in FIG. **3**.

In block **305**, the EEC **250** may initialize a variable time span TS to zero. In one embodiment, the time span TS may represent a time window during which all the input frames are different from the no-event frame while there is no occurrence of an event in the input frames. In one embodiment, a large TS value may imply that the current 'no-event' frame may not be valid anymore and a new 'no-event' frame may need to be re-established.

In block **310**, the EEC **250** may invalidate the present 'no-event frame'. In one embodiment, the present 'no-event frame' is invalidated to set-up a new 'no-event frame', which may provide an accurate reference that may represent the scenario at scene **110-1** before capturing any event.

For example, the present 'no-event frame', which is invalidated in block **305** may represent a parking lot with sunshine. However, a cloud may move over the parking lot after sometime and before the event is captured, a new 'no-event frame' may be established with a cloud over the parking lot. In one embodiment, the EEC **250** may invalidate the present 'no-event frame' (parking lot with sun shine) and re-establish a new 'no-event frame' (parking lot with clouds) to avoid false alarms. In one embodiment, the frame **510** (F(ne)) of FIG. **5** may represent a re-established 'no-event' frame, which may represent a cloud covered parking lot.

In block **315**, the EEC **250** may retrieve a new frame F(n) from the frame buffer **230**. In one embodiment, the EEC **250** may retrieve a frame **520** (=F(n)) of FIG. **5** that may be captured and stored in the frame buffer **230**. In block **320**, the EEC **250** may check whether a valid 'no-event' F(ne) is established and control passes to block **325** if the 'no-event' frame is valid and to block **370** otherwise.

In block **325**, the EEC **250** may compute the difference between F(n) (frame **520**) and F(ne) (frame **510**) and control may pass to block **330**. In block **330**, the EEC **250** may check whether the difference between F(n) (frame **520**) and F(ne) (frame **510**) is greater than the threshold value and control passes to block **335** if the difference between F(n) (frame **520**) and F(ne) (frame **510**) is lesser than the threshold value and to block **345** if the difference between F(n) and F(ne) is greater than the threshold value.

In block **335**, the EEC **250** may initialize the time span to zero. In block **340**, the EEC **250** may mark the frame F(n) as the 'no-event' frame and transmit the 'no-event frame' to the central computer system **190**. Control passes to block **315**. In one embodiment, the difference between frame **520** and **510** may be lesser than the threshold value if the car has not entered the parking lot. Thus, the frame **520** may be marked as 'no-event' frame.

In block **345**, the EEC **250** may compute the difference between a frame F(n−1) received prior to the new frame F(n). In block **350**, the EEC **250** may check whether the difference between F(n) and F(n−1) is greater than the threshold value and control passes to block **355** if the difference between F(n) and F(n−1) is greater than a threshold value and to block **360** otherwise. In block **352**, the EEC **250** may initialize the time span to zero.

In block **355**, the EEC **250** may compute and compress the action of the moving objects. In block **358**, the EEC **250** may compress the identity of the moving objects. In block **359**, the EEC **250** may transmit the 'event frame' (frame **520**) to the central computer system **190**.

In block **360**, the EEC **250** may increment the time span (TS) and control passes to block **363**. In block **363**, the EEC **250** may check whether the value of TS is greater than the time duration 'K" and control passes to block **310** if the value of TS is greater than the time duration K and to block **355** otherwise.

In block **370**, the EEC **250** may transmit a null tag. In one embodiment, the null tag may indicate that the 'no-event frame' is yet to be established. In block **374**, the EEC **250** may compute the difference between the frame F(n−1) received prior to the new frame F(n).

In block **378**, the EEC **250** may check whether the difference between F(n) and F(n−1) is greater than the threshold value and control passes to block **380** if the difference between F(n) and F(n−1) is greater than the threshold value and to block **390** otherwise.

In block **380**, the EEC **250** may initialize the time span to zero and control passes to block **315**. In block **390**, the EEC **250** may increment the time span (TS) and control passes to block **394**.

In block **394**, the EEC **250** may check whether the value of TS is greater than the time duration 'K" and control passes to block **398** if the value of TS is greater than the time duration K and to block **315** otherwise. In block **398**, the EEC **250** may validate F(ne) frame by replacing the 'no-event frame' F(ne) with the new frame F(n).

An operation of the EAVS enabled controller (EEC) **250** of the event aware video system (EAVS) **150** computing and compressing the event information in the event frame in accordance with one embodiment is illustrated in FIG. **4**.

In block **405**, the EEC **250** may remove the background information from the 'event frame' (frame **520**). In one embodiment, the EEC **250** may generate the frame **560** after removing the background information from the frame **520**. In one embodiment, the EEC **250** may comprise a finite impulse response (FIR) filter, which may compare every pixel of the new frame F(n) against a corresponding pixel in the 'no-event

frame' F(ne). After comparison, the EEC **250** may identify pixels in which the difference of color levels in F(ne) and F(n) is lesser than the threshold value. In one embodiment, the EEC **250** may mark all the pixels with difference lesser than the threshold value as a portion of the background.

In one embodiment, the color levels for red (R), green (G), and blue (B) of the pixels identified as a portion of the background may be set to represent black color. In one embodiment, setting the color levels of the pixels to black may be equivalent to removing the background information. In one embodiment, the new frame F(n) in which the background information may be removed may be referred to as a background removed frame BRF(n). In one embodiment, the FIR filter may comprise a multiplier, an accumulator, memory rows, and DMA logic to perform filtering and removal of background information. In one embodiment, the EEC **250** may generate a 1-bit bit-map b(n), which may indicate the position of the moving objects in the background removed present frame BRF(n). In one embodiment, the bit-map b(n) may indicate whether each pixel of the frame BRF(n) is a portion of the moving object or the background. For example, the pixels 3-8 of row-1 and pixels 1 to 14 of row-2 may represent a portion of the moving object and the bit-map b(n) may comprise a first logic value (e.g., 1) for these pixels (3 to 8 of row-1 and 1 to 14 of row-2) and for the remaining pixels, the bit-map b(n) may comprise a second logic value (e.g., 0).

However, to identify an event, the frames **520** and **530** are captured at higher rate. For example, the new frame **520** captured at time point T**1** may become a previous frame after a next frame **530** is captured at time point T**2**, wherein T**1** occurs prior to T**2**. In one embodiment, the frame F(n) (frame **530**) may represent a new frame captured at the most recent time point T**2**, BRF(n) (frame **570**) may represent the frame F(n) (frame **530**) from which the background information is removed, and b(n) may represent the bit-map of the BRF(n) (frame **570**). In one embodiment, the frame **520** captured immediately prior to F(n) may be referred to as a previous frame F(n−1) and BRF(n−1) (frame **560**) may represent the previous frame F(n−1) (frame **520**) from which the background information is removed, and b(n−1) may represent the bit-map of the BRF(n−1). In one embodiment, a bit-map b(n−1) may indicate the position of the moving objects in the frame BRF(n−1).

In block **410**, the EEC **250** may label the moving objects that represent an event. In one embodiment, the event frame may comprise one or more moving objects and the EEC **250** may label each of the moving objects with an identifier (moving object ID). In one embodiment, the EEC **250** may scan the bit-map b(n) and the frame BRF(n) before labeling the moving objects and may label the moving objects using a variable 'i', wherein 'i' may be a positive integer value (e.g., i=1, 2, 3 . . . L) identifying each of the moving objects, where L is the total number of the moving objects in the frame. For each pixel in the BRF(n) may be logically labeled as either belonging to one of the moving objects or the background. Also, for each moving object, the EEC **250** may collect a statistics vector V(i, k), wherein 'i' may represent the moving object ID and 'k' may represent index of the frame. In one embodiment, the statistics vector may include size and location of a bounding rectangle in the BRF(n), total mass of Y, U, and V components of the moving object, location of the gravity center of Y component of each of the moving objects, and such other similar statistics, which may allow accurate identification of the moving objects.

In block **415**, the EEC **250** may pair the moving objects in the new frame BRF(n) (frame **570**) and the previous frame BRF(n−1) (frame **560**). In one embodiment, the EEC **250** may pair the moving objects using the statistics vector V(i, k) and V(i', k−1) determined in block **410**. In one embodiment, the EEC **250** may detect the pairs corresponding to the moving objects in BRF(n) and BRF(n−1). In one embodiment, the EEC **250** may determine a corresponding moving object in BRF(n−1) for each moving object in BRF(n) such that both the moving objects represent the same portion of the event frame. In one embodiment, the EEC **250** may perform pairing based on statistics V(i, k) of BRF(n) and V(i', k−1) of BRF (n−1) using the following principles: Suppose O(i, k) and O(i', k−1) are the two objects corresponding to V(i, k) and V(i', k−1), then,

a. If the total masses of V(i, k) scaled to the bounding rectangle's area of V(i, k) are similar to the same quantity of V(i', k−1), then O(i, k) and O(i', k−1) are more likely to be the same object;

b. If the location of gravity center of V(i, k) relative to the center of the bounding rectangle of V(i, k) is similar to the same quantity of V(i', k−1), then O(i, k) and O(i', k−1) are more likely to be the same object; For example, if the location of gravity of center of V(i, k) is Lgi and that of V(i', k−1) is Lgi' and if the center of the bounding rectangle of V(i, k) is Lbi and that of V(i', k−1) is Lbi', then if {(Lgi−Lbi)−(Lgi'−Lbi')} is zero or very small then O(i, k) and O(i', k−1) are more likely to be the same object; and

c. There may exist utmost one O(i', k−1) to match O(i, k).

In one embodiment, as a result of the object pairing, EEC **250** may determine the object-level motion vector, which indicates the spatial shift between the location of gravity center of O(i', k−1) and the location of gravity center of O(i, k).

In block **420**, the EEC **250** may resize the pre-paired moving objects. In one embodiment, for each paired object in BRF(n) and BRF(n−1), the EEC **250** may resize the bounding rectangle in BRF(n) such that the bounding rectangle in BRF (n) may have a size same as that of the bounding rectangle in BRF(n−1). In other embodiment, for each paired object in BRF(n) and BRF(n−1), the EEC **250** may resize the bounding rectangle in BRF(n−1) such that the bounding rectangle in BRF(n−1) may have a size same as that of the bounding rectangle in BRF(n). In one embodiment, the EEC **250** may choose the size of the bounding rectangle to be less than $1/5^{th}$ of the total image size. In one embodiment, the EEC **250** may perform interpolation on the Y-component of the pixels present in the resized moving objects. In one embodiment, the Y-component interpolation in BRF(n) may result in Y(i, k), which may cover O(i, k). In one embodiment, the Y-component interpolation in BRF(n−1) may result in Y(i', k−1), which may cover O(i', k−1).

In one embodiment, the resizing the pre-paired moving objects may improve accuracy of the motion vector estimate and reduce the motion error. In one embodiment, the resizing of the per-paired moving objects may be performed to maintain the size of the moving objects. In one embodiment, maintaining the size of the moving objects may improve the accuracy as it is easier to estimate the motion vector for a moving object if the size of the moving object does not change the size in the view as compared to estimating the motion vector for the moving object changing its size in the view. In one embodiment, the removal of background may allow per-paired resizing of the moving objects. In one embodiment, the resizing may be performed using linear interpolation of pixels.

For example, the size of the bounding rectangle B(k−1) of the frame BRF(n−1) may equal Q (=3×3 pixel matrix) and the bounding rectangle B(k) of the frame BRF(n) may equal Z

(=2×2) pixel matrix. In one embodiment, the size Q may be made equal to Z before processing the frame BRF(n). In one embodiment, Q (a 3×3 pixel matrix) may comprise elements {(1, 2, 3), (4, 5, 6), and (7, 8, 9) in the first, second, and third row respectively]. In one embodiment, the 3×3 pixel matrix may be resized into a 2×2 pixel matrix comprising elements {(3, 4), (6, 7)}. In one embodiment, the first element (=3) may be generated by summing the first four elements (1+2+4+5=12) of the top left 2×2 matrix comprising elements (1, 2, 4, 5) and dividing the sum by the number of elements (=4) in the top left 2×2 matrix. Like-wise the remaining elements (4, 6, and 7) of the 2×2 matrix may be determined. The resulting resized 2×2 matrix may comprise elements {(3, 4), (6, 7)}.

In block **430**, the EEC **250** may determine a real motion vector (V) of the moving object. In one embodiment, EEC **250** may determine the real motion vector by computing the center of gravity of the bounding rectangles B(k) (**575**) and B(k−1) (**565**) and the difference between the center of gravity of B(k) (**575**) and B(k−1) (**565**) may represent the real motion vector. In one embodiment, the location of the gravity centers of V(i, k) and V(i', k−1) may provide the motion vector of the moving objects. In one embodiment, in the previous frame, the bounding rectangle B(k−1) for an object may be centered at coordinate (X,Y)=(7, 13) and the pixels inside B(k−1) may equal {(1, 2), (3, 4)}. In one embodiment, in the current frame, the bounding rectangle B(k) for the same object may be centered at coordinate (X,Y)=(25, 49) and the pixels inside the B(k−1) may equal {(9, 7), (10, 8)}. In one embodiment, the coordinate of the gravity center of B(k−1) may equal (X,Y)=(7.1, 12.8) and the gravity center of B(k) may equal (X,Y)=(24.94, 48.97). In one embodiment, the gravity center may be computed for B(k−1) and B(k) as follows:

For B(k−1), X-coordinate=(7−0.5)*(1+3)/(1+2+3+4)+(7+0.5)*(2+4)/(1+2+3+4)=7.1; and Y-coordinate=(13−0.5)*(3+4)/(1+2+3+4)+(13+0.5)*(1+2)/(1+2+3+4)=12.8.

For B(k), X-coordinate=(25−0.5)*(9+10)/(7+8+9+10)+(25+0.5)*(7+8)/(7+8+9+10)=24.94; and Y-coordinate=(49−0.5)*(10+8)/(7+8+9+10)+(49+0.5)*(9+7)/(7+8+9+10)=48.

In one embodiment, the real motion vector derived from the gravity centers from B(k−1) to B(k) is then: (24.94−7.1, 48.97−12.8)=(17.84, 36.17).

In one embodiment, the internal objects within each moving object may also move and the movement of internal objects with each moving object may be determined using one dimensional search as described in FIG. **6** and FIG. **7**.

In block **450**, the EEC **250** may estimate the motion error. In one embodiment, the EEC **250** may shift the moving object in B(k−1) by the real motion vector to generate an estimated moving object in B(k). In one embodiment, the EEC **250** may determine the motion error by computing the difference between the real and the estimated motion vector. In one embodiment, the EEC **250** may estimate the motion error by computing the difference between Y(i, k) and the motion estimate of Y(i, k) based on the motion vectors Y(i, k) and Y(i', k−1). In one embodiment, the motion vector from B(k−1) to B(k) may be used to shift the moving object in B(k−1) by an amount V to become motion estimated B(k), called B'(k). In one embodiment, the estimated motion vector from B(k−1) to B(k) may be determined by shifting the moving object in B(k−1) by an amount V to get motion estimated B(k), called B'(k), the error 'e' may be computed using e=[B(k)−B'(k)].

In block **470**, the EEC **250** may determine if the motion error is greater than the allowable error threshold and control passes to block **480** if the motion error is greater than the allowable error threshold and to block **490** if the motion error is lesser than the allowable error threshold. In one embodiment, the EEC **250** may compare the error 'e' with an allowable error threshold and if the error 'e' is greater than the allowable error threshold value, then the refined motion estimate for the bounding box B(k) may be performed by dividing the bounding box B(k) into 'X' smaller rectangles, for example, Bsmall(k, m), m=1, 2, 3, 4.

In block **480**, the EEC **250** may perform motion refining and control passes to block **450**. In one embodiment, for each smaller rectangle Bsmall(k, m), a traditional motion search may be performed by moving Bsmall(k, m) around within B(k−1) to find the best match between Bsmall(k, m) and a rectangle of the same size in B(k−1). In one embodiment, such an approach may generate four motion vectors V(m), m=1, 2, 3, 4, for each of the smaller rectangles. In one embodiment, the motion error for each of the smaller rectangles may be determined as described above. If the error is small enough, the refining of the motion error for that particular small rectangle may be considered as completed. However, if the error is larger, the smaller rectangle may be further divided into the smaller rectangles into, for example, X smaller rectangles and the motion estimation may be performed again for the smaller rectangles. In one embodiment, the process may be continued until motion errors are all within the limit. Such as process may be referred to as "Motion refining".

In block **490**, the EEC **250** may perform motion vector and motion error coding. In one embodiment, the EEC **250** may perform encoding using, for example, discrete cosine transform (DCT) on the motion errors of YUV, quantization of the DCT coefficients, compression of motion errors, and such other similar operations. In one embodiment, the event information such as the bounding rectangles of all the moving objects, object level motion vectors of the all the moving objects, object pairing and resizing factors, encoded and compressed values of motion errors may be sent over the network to the central computer system **190**.

An operation of the EAVS enabled controller (EEC) **250** of the event aware video system (EAVS) **150** performing one dimensional search for motion estimation in accordance with one embodiment is illustrated in FIG. **6**.

In block **610**, the EEC **250** may divide the boundary rectangle B(k) into sub-rectangles. In one embodiment, the EEC **250** may divide the boundary rectangle B(k) (rectangle **575**) into 8×8 sub-rectangles {(**791-1** to **791-8**), (**792-1** to **792-8**), (**793-1** to **793-8**), (**794-1** to **794-8**), (**795-1** to **795-8**), (**796-1** to **796-8**), (**797-1** to **797-8**), (**798-1** to **798-8**) of FIG. **7**}.

In block **620**, the EEC **250** may identify border rectangles in the boundary rectangle B(k) (rectangle **575**). In one embodiment, the EEC **250** may identify a sub-rectangle as a sub-border rectangle if the sub-rectangle comprises a J**1** percentage of background pixels and J**2** percentage of object pixels. In one embodiment, the border sub-rectangles (**792-5**, **792-6**, **793-8**, **794-8**, **794-7**, **795-7**, **795-6**, **796-6**, **797-5**, **797-4**, **797-3**, **797-2**, **796-2**, **795-2**, **794-3**, and **793-4**) may comprise at least 10% (=J**1**) of background pixels and 10% (=J**2**) of object pixels.

In block **630**, the EEC **250** may designate a pivotal border pixel for each border sub-rectangle. In one embodiment, the EEC **250** may identify an object pixel in each border sub-rectangle that is nearest to the center of the border sub-rectangle. For example, in border sub-rectangle **796-6**, the EEC **250** may designate object pixel **780** as the pivotal border pixel as the object pixel **780** is nearest to the center of the border sub-rectangle **796-6**. In one embodiment, the EEC **250** may designate a pivotal border pixel for each border sub-rectangle. For example, the EEC **250** may designate object pixels **774**, **775**, and **776** of the boundary sub-rectangles **797-2**, **797-3**, and **797-4** as the pivotal border pixels.

In block **650**, the EEC **250** may determine the motion vector for each border sub-rectangle by comparing the border sub-rectangle of B(k) (**575**) led by the pivotal border pixel with the border of B(k−1) (**565**). In one embodiment, the EEC **250** may chose the border sub-rectangle **796-6** led by the pivotal pixel **780** and compare the border sub-rectangle **796-6** with the border sub-rectangles of the bounding rectangle B(k−1) (**565**) to determine a best match in the pixel's Y-co-ordinate value. As the bounding rectangles **565** and **575** are of same size and the object inside the bounding rectangles may be of same size as well, the search to determine a best match in the pixel's Y-coordinate value may provide an estimate of the motion vector. In one embodiment, the position of the best matching pixels between the previous frame and the present frame provides an estimate of the displacement of the movement of the objects within the moving object.

In one embodiment, by observation, the search is reduced from a two-dimensional search to a one-dimensional search. As a result of performing one dimensional search, the processor cycles or computational resources may be conserved. In one embodiment, as a result of one-dimensional search, the computational resources may be conserved by a 60:1 reduction factor.

In block **670**, the EEC **250** may determine the motion vector of the non-border sub-rectangles (**793-5**, **793-6**, **793-7**, **794-4**, **794-5**, **794-6**, **795-3**, **795-4**, **795-5**, **796-3**, **796-4**, and **796-5**) using the motion vectors of the border sub-rectangles. In one embodiment, the EEC **250** may determine the motion vectors of the non-border sub-rectangles by interpolating the motion vectors of the border sub-rectangles. In one embodiment, the EEC **250** may use standard-2 dimensional spline interpolation approach to determine the motion vectors of the non-border sub-rectangles.

In block **690**, the EEC **250** may perform motion refining for the sub-rectangles in B(k) within which the motion of the object is non-linear. In one embodiment, the motion vectors obtained in blocks **650** and **670** may be used as a starting point to perform the motion refining for the sub-rectangles in B(k). Such an approach may also reduce the computational resources required to perform motion refining.

Certain features of the invention have been described with reference to example embodiments. However, the description is not intended to be construed in a limiting sense. Various modifications of the example embodiments, as well as other embodiments of the invention, which are apparent to persons skilled in the art to which the invention pertains are deemed to lie within the spirit and scope of the invention.

What is claimed is:

1. A method in a video capturing device comprising:

capturing a first plurality of video frames during a first time period;

establishing a present no-event frame from the first plurality of video frames, wherein a last frame of the first plurality of video frames is marked as the present no-event frame if the difference between adjacent pair of frames of the first plurality of video frames is less than a threshold value;

establishing an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame captured prior to the present frame is greater than the threshold value;

generating event information including motion vectors, wherein the motion vectors represent displacement of a plurality of objects moving within a moving object, wherein the motion vectors are generated by performing one-dimensional search on a moving object of the event frame; and

generating a real motion vector of a moving object in the event frame, wherein generating the real motion vector comprises:

labeling the moving object;

pairing the moving object in the event frame with a moving object in the previous frame;

resizing a boundary of the moving object in the event frame to match a boundary of the moving object in the previous frame; and

computing the co-ordinates of the center of gravity of the boundary of the moving object in the event frame and the previous frame.

2. The method of claim **1**, wherein generating the motion vectors comprise rejecting the present frame captured after the first time period if the difference between the present frame and the no-event frame is less than the threshold value.

3. The method of claim **1**, wherein generating the motion vectors comprises removing background information of the event frame before sending the event information to the central computing system.

4. The method of claim **3**, wherein removing the background comprises:

identifying an area that excludes the event in the event frame; and

assigning a first color value to the pixels of the area, wherein assigning the first color to the pixels of the area removes the background information in the event frame.

5. The method of claim **1** further comprises computing motion error of the moving object including:

generating an estimated motion vector by displacing the moving object in the previous frame using the motion vector; and

computing the difference between the real moving object image and the motion estimated moving object image.

6. The method of claim **5** further comprises:

performing motion refining if the motion error is greater than an allowable error threshold; and

performing motion error coding if the motion error is lesser than the allowable error threshold.

7. A method in a video capturing device comprising:

capturing a first plurality of video frames during a first time period;

establishing a present no-event frame from the first plurality of video frames, wherein a last frame of the first plurality of video frames is marked as the present no-event frame if the difference between adjacent pair of frames of the first plurality of video frames is less than a threshold value;

establishing an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame captured prior to the present frame is greater than the threshold value; and

generating event information including motion vectors, wherein the motion vectors represent displacement of a plurality of objects moving within a moving object, wherein the motion vectors are generated by performing one-dimensional search on a moving object of the event frame;

wherein generating each of the motion vectors comprises dividing the boundary of the moving object in the event frame into a plurality of sub-rectangles, and determining motion of the object within the plurality of sub-rectangles.

8. The method of claim 7, wherein generating the motion vectors comprises identifying border sub-rectangles of the plurality of sub-rectangles, wherein a sub-rectangle of the plurality of sub-rectangles is identified as a border sub-rectangle if the sub-rectangle includes at least a first quantity of background pixels and at least a second quantity of object pixels.

9. The method of claim 7, wherein generating the motion vectors comprise designating a pivotal border pixel for the border sub-rectangles, wherein a pixel nearest to the center of the border sub-rectangle is designated as the pivotal border pixel.

10. The method of claim 9, wherein generating the motion vectors comprise:

determining motion vectors for the border sub-rectangles by comparing the border sub-rectangle of the event frame led by the pivotal border pixel with the border of the previous frame; and

determining motion vectors for non-border sub-rectangles using the motion vectors of the border sub-rectangles, wherein the sub-rectangles other than the border sub-rectangles of the plurality of sub-rectangles is identified as non-border sub-rectangles.

11. An apparatus comprising:

an image capturing unit to capture a first plurality of video frames during a first time period;

an event aware video system enabled controller coupled to the image capturing unit, wherein the event aware video system enabled controller is to:

establish a present no-event frame from the first plurality of video frames, wherein a last frame of the first plurality of video frames is marked as the present no-event frame if the difference between adjacent pair of frames of the first plurality of video frames is less than a threshold value; and

establish an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame captured prior to the present frame is greater than the threshold value; and

generate event information including motion vectors, wherein the motion vectors represent displacement of a plurality of objects moving within a moving object, wherein each of the motion vectors is generated by performing one-dimensional search on a moving object of the event frame; and

to generate a real motion vector of a moving object in the event frame, the event aware video system enabled controller is to:

label the moving object,

pair the moving object in the event frame with a moving object in the previous frame,

resize a boundary of the moving object in the event frame to match a boundary of the moving object in the previous frame, and

compute the co-ordinates of the center of gravity of the boundary of the moving object in the event frame and the previous frame.

12. The apparatus of claim 11, wherein the event aware video system enabled controller is to reject the present frame captured after the first time period if the difference between the present frame and the no-event frame is less than the threshold value.

13. The apparatus of claim 11, wherein the event aware video system enabled controller is to remove background information of the event frame before sending the event information to the central computing system.

14. The apparatus of claim 13, wherein the event aware video system enabled controller is to:

identify an area that excludes the event in the event frame; and

assign a first color value to the pixels of the area, wherein assigning the first color to the pixels of the area removes the background information in the event frame.

15. The apparatus of claim 11, wherein the event aware video system enabled controller is to:

generate an estimated motion vector by displacing the moving object in the previous frame using the motion vector; and

compute the difference between the real moving object image and the motion estimated moving object image.

16. The apparatus of claim 15, wherein the event aware video system enabled controller is to:

perform motion refining if the motion error is greater than an allowable error threshold; and

perform motion error coding if the motion error is lesser than the allowable error threshold.

17. An apparatus comprising:

an image capturing unit to capture a first plurality of video frames during a first time period;

an event aware video system enabled controller coupled to the image capturing unit, wherein the event aware video system enabled controller is to:

establish a present no-event frame from the first plurality of video frames, wherein a last frame of the first plurality of video frames is marked as the present no-event frame if the difference between adjacent pair of frames of the first plurality of video frames is less than a threshold value;

establish an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame captured prior to the present frame is greater than the threshold value;

generate event information including motion vectors, wherein the motion vectors represent displacement of a plurality of objects moving within a moving object, wherein each of the motion vectors is generated by performing one-dimensional search on a moving object of the event frame;

divide the boundary of the moving object in the event frame into a plurality of sub-rectangles; and

determine motion of the object within the plurality of sub-rectangles.

18. The apparatus of claim 17, wherein the event aware video system enabled controller is to identify border sub-rectangles of the plurality of sub-rectangles, wherein a sub-rectangle of the plurality of sub-rectangles is identified as a border sub-rectangle if the sub-rectangle includes at least a first quantity of background pixels and at least a second quantity of object pixels.

19. The apparatus of claim 17, wherein the event aware video system enabled controller is to designate a pivotal border pixel for the border sub-rectangles, wherein a pixel nearest to the center of the border sub-rectangle is designated as the pivotal border pixel.

20. The apparatus of claim 19, wherein the event aware video system enabled controller is to:

determine motion vectors for the border sub-rectangles by comparing the border sub-rectangle of the event frame led by the pivotal border pixel with the border of the previous frame; and

determine motion vectors for non-border sub-rectangles using the motion vectors of the border sub-rectangles, wherein the sub-rectangles other than the border sub-

rectangles of the plurality of sub-rectangles is identified as non-border sub-rectangles.

21. A system comprising:

a central computer system, coupled to a network to receive event information; and

an event aware video system coupled to the network, wherein the event aware video system is to transfer the event information over the network;

wherein the event aware video system is to establish a present no-event frame from the first plurality of video frames, wherein a last frame of the first plurality of video frames is marked as the present no-event frame if the difference between adjacent pair of frames of the first plurality of video frames is less than a threshold value; and

wherein the event aware video system is to establish an event frame, wherein a present frame captured after establishing the no-event frame is marked as the event frame if the difference between the present frame and a previous frame captured prior to the present frame is greater than the threshold value; and

wherein the event aware video system is to generate event information including motion vectors, wherein the motion vectors represent displacement of a plurality of objects moving within a moving object, wherein the motion vectors is generated by performing one-dimensional search on a moving object of the event frame;

wherein the event aware video system is to divide the boundary of the moving object in the event frame into a plurality of sub-rectangles;

wherein the event aware video system is to identify border sub-rectangles of the plurality of sub-rectangles, wherein a sub-rectangle of the plurality of sub-rectangles is identified as a border sub-rectangle if the sub-rectangle includes at least a first quantity of background pixels and at least a second quantity of object pixels; and

wherein the event aware video system is to determine motion of the object within the plurality of sub-rectangles.

22. The system of claim **21**, wherein the event aware video system is to:

designate a pivotal border pixel for the border sub-rectangles, wherein a pixel nearest to the center of the border sub-rectangle is designated as the pivotal border pixel;

determine motion vectors for the border sub-rectangles by comparing the border sub-rectangle of the event frame led by the pivotal border pixel with the border of the previous frame; and

determine motion vectors for non-border sub-rectangles using the motion vectors of the border sub-rectangles, wherein the sub-rectangles other than the border sub-rectangles of the plurality of sub-rectangles is identified as non-border sub-rectangles.

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